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**SKILL ACQUISITION AND TRANSFER: THE EFFECT OF PRACTICE ON
PERFORMANCE.**

By

Tracey Piani

**A Thesis Submitted in Partial Fulfillment of the
Requirements for the Award of
Bachelor of Arts (Psychology) Honours
at the Faculty of Community Services, Education
and Social Sciences,
Edith Cowan University.**

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SKILL ACQUISITION AND TRANSFER: THE EFFECT OF PRACTICE ON PERFORMANCE.

Abstract

This study was designed to examine the effect of amount of training on the specificity of skill acquisition and transfer. Within the theoretical framework of two contemporary theories of skill acquisition, Anderson's ACT* theory (1982, 1987), and Logan's Instance theory of automisation (1988, 1990), the study extends research by Greig and Speelman (in press) that demonstrated skills can be both general (i.e., can apply beyond the training experience) and specific (i.e., are limited to training experiences). The experiment was divided into training and transfer phases. The amount of practice in the training phase was manipulated across three experimental conditions, with 14 participants in each condition. Participants were required to practice applying a small set of paired x and y values to a simple algebraic equation. The set of values for x and y was held constant during training, with a new set of values presented in the transfer phase. It was anticipated that training would result in improved performance, with those participants who received the greatest amount of training ultimately performing better on the training task. It was further anticipated these participants would demonstrate greater disruption on their initial performance on the transfer task, indicating greater specificity of skills to the items presented in the training phase. The results were similar to those reported by Greig and Speelman in that participants displayed evidence that both general and specific skill had been acquired. Furthermore, those participants who received the greatest amount of training also experienced the greatest amount of disruption in performance when presented with the transfer task. These results suggest that while the participants' skill was not totally specific to the items experienced in training, it was also not completely generalisable to different tasks. Results failed to differentiate between the three groups' performance in the transfer phase of the experiment as a function of the amount of practice each group received during the training phase. Reasons for this lack of difference between the groups' performance on the transfer task are discussed in the context of future research implications. The findings of the study are discussed in relation to the ACT* theory and the Instance theory, with the conclusion that the results provide the greatest support for the ACT* theory.

Author: Tracey Piani
Supervisor: Dr. Craig*Speelman
Submitted: 30th October 1998

Declaration

"I certify that this thesis does not incorporate, without acknowledgement, any other material previously submitted for a degree or diploma in any institution of higher education and that, to the best of my knowledge and belief, it does not contain any material previously published or written by another person, except where due reference is made in the text".

Signed: Date: 30/10/98

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Table of Contents

	Page
Title Page.....	i
Abstract.....	ii
Declaration.....	iii
Acknowledgements.....	iv
Table of Contents.....	v
List of Tables.....	viii
List of Figures.....	ix
 Introduction.....	 1
Background.....	2
Automaticity.....	3
The Three Phases of Skill Acquisition.....	5
The Power Law of Practice.....	6
The ACT* Theory.....	7
The Instance Theory of Automisation.....	12
Transfer.....	14
Transfer: Empirical Evidence.....	14
Transfer: Theoretical Explanations.....	17
The Current Study.....	19

Introduction

Upon completing a course in word processing, individuals often notice that they type slower and make more errors when they first apply these skills outside the classroom, especially if they are required to use a different type of computer with different software (Smith, Zirkler & Mynatt, 1985; Speelman & Kirsner, 1993). In short, their initial performance declines. This presents a major challenge for designers of skill based programmes in relation to determining what skills to include in the training programme and how much prior practice the individual user requires in the training environment to ensure that skills are transferable (Hesketh, 1994). The aim of learning a skill in a controlled training environment is that the skill will be efficiently transferred to a real life setting. Therefore the factors that influence the transfer of the skill are fundamental to the overall success of the training. Recent research has examined the impact of previously acquired skills on performance of a new task, focusing on the factors that facilitate learning and transfer of skills (Hesketh, 1994; Speelman & Kirsner, 1993). The efficiency with which previously acquired skills can be applied to a new task has been found to be dependent upon the context in which they are acquired. The relationship between the nature of the training environment and the acquired knowledge is therefore fundamental to the transfer of skills to different tasks and settings (Hesketh, 1994).

The study described in this thesis was designed to explore the relationship between training and performance, focusing on two key issues. The first concerns whether skills are general or specific. The second relates to the factors, specifically the amount of training, that may influence whether skills are general or specific.

General skills are those skills that can be executed in response to similar yet different

tasks. Specific skills apply to a particular set of stimulus conditions only, offering no assistance with performance when a new task is presented. To determine whether skills are general or specific, transfer of performance from old to new tasks is examined. Transfer can be defined as the extent to which skills acquired during performance of one task can influence performance on a different yet similar task. (Kramer, Stayer, & Buckley, 1990).

Recent research on the nature of skill acquisition is divided between two opposing theories, the ACT* theory (Anderson, 1982, 1987, 1992), and the Instance theory of automatization (Logan, 1988, 1990). The ACT* theory provides a comprehensive account for the manner in which general skills are acquired. Furthermore, it offers an explanation as to how specific skills may be also acquired. Skilled knowledge is perceived to be abstract, thus enabling Anderson (1982; 1987) to make predictions that skills can be applied beyond training experiences. In contrast, the Instance theory (Logan, 1988; 1990) proposes that skills are highly specific in nature, constrained to the events encountered during training. A detailed description of both the ACT* and the Instance theories and the way in which they account for the fundamental phenomena associated with skill acquisition is presented below. Transfer predictions based on these accounts were tested in the current experiment.

Background

A significant amount of recent research has focused on the theoretical and empirical aspects of skill acquisition (e.g., Corbett & Anderson, 1989; Kieras & Bovair, 1986; Logan & Stadler, 1991; Masson, 1990; Singly & Anderson, 1989).

Common elements that forge a link between the proposed theoretical arguments and the empirical research are the assumptions that: (1) practice can lead to improved performance and (2) the amount of transfer of skill from one task to a subsequent task is dependent on the number of shared elements between the tasks (Frensch, 1991; Pirolli & Anderson, 1995; Speelman & Kirsner, 1997). The implication of the link between practice and performance is such that a task that initially required the individual's full attention and substantial effort can, after practice, be carried out effortlessly, faster and with greater accuracy (Anderson, 1982; Brown & Carr, 1989; Logan, 1988; 1990; Shiffrin & Schneider, 1977). While most current researchers agree that practice can lead to skilled performance, there is debate over the nature of the learning mechanisms involved and what forms of practice lead to the best performance (Adams, 1987; Speelman & Kirsner, 1997). While performance has the potential to change with practice, the direction and benefit of this change is not absolute with research demonstrating that different forms of practice lead to different levels of performance (Schneider, Dumais, & Shiffrin, 1984; Speelman & Kirsner, 1997).

Automaticity

Most theories of skill acquisition highlight practice as an essential element in the process of automaticity necessary to bring about changes in cognitive behaviour and reduction in attentional demands. In the early stages of automaticity the process is controlled, while information is processed automatically during the later stages, as a product of practice and subsequent learning (Bargh, 1992; Logan, 1988; Logan & Klapp, 1991). A study by Shiffrin and Schneider (1977) outlined the main differences

between controlled and automatic processing, in which they elaborate on the role and type of practice that leads to controlled processing becoming automatic. Controlled processing is when there is willful attention to the task at hand. Controlled processing requires a high level of attention in order to process information, it usually occurs in a serial manner, it is easily altered and effortful. Controlled search is error-prone with the outcome of the attentional search (i.e., speed and accuracy) heavily contingent upon the amount and depth of the information being processed. Limitations on controlled processing are reflections of the attentional capacity in short-term memory.

In contrast, automatic processing is developed through extended practice, typically when subjects process particular stimuli consistently over many trials (Schneider et al., 1984; Shiffrin & Schneider, 1977). Characteristically it is faster, effortless and error-free. Once an automatic process is incorporated into long term memory, information is processed in a parallel manner. As a result automatic processes are less affected by concurrent processes and are not influenced by alternative solutions to the task at hand. The process is not directly under the person's control, with the skill difficult to ignore or alter once learned. Automatic processes are virtually unaffected by load, indicating that increases in the amount of stimuli and changes to presentation do not influence the speed and accuracy at which processing occurs (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977).

An individual reaches the stage of automaticity when they can perform routine activities effortlessly and quickly, with little conscious thought or mindfulness (Brown & Carr, 1989; Logan, 1988). As skills can be conceptualized as large collections of automatic processes and procedures, automaticity is an important component of skill acquisition (Logan 1988).

The Three Phases of Skill Acquisition

Skill acquisition can be conceptualized as a three stage process (Fitts, 1964).

The initial *cognitive phase*, as described by Fitts (1964), lasts for only a few trials while the individual learns the instructions and formulates performance strategies. This stage involves significant attentional resources, as the developing strategies are based upon general strategies consisting of knowledge learned from experience with previous tasks. Knowledge is rule-based and explicit with the subsequent performance slow and error prone. In the second stage, *the associative stage*, performance is refined. Strategies learned in the previous stage are strengthened if they contain features appropriate to the task, while strategies containing unsuitable features are weakened. This feedback mechanism enhances the development of new associations between stimulus-specific cues and appropriate responses. During the final stage, *the autonomous stage*, skills become faster and more efficient, with the components of the performance strategy less contingent on external influences or cognitive control. As performance of the task requires increasingly less processing, the rate of improvement with each subsequent performance episode slows, at which stage automaticity is reached

Shiffrin and Schneider (1977; Schneider & Shiffrin, 1977) proposed a three phase model of human information processing, in which the qualitative differences in performance at each stage are believed to result from the shift from controlled processing to automatic processing. Performance in the initial phase is dictated by controlled processes, with the combination of controlled and automatic processes influencing performance in the second phase. The third and final phase is characterized by automatic processing.

The Power Law of Practice

In a typical skill acquisition study, participants repeatedly practice a task, receiving feedback at the end of each trial (i.e., correct or incorrect), with the response recorded on two levels, accuracy and reaction time (Speelman & Maybery, 1998). The typical response pattern to emerge shows dramatic improvement in participants' reaction times from one trial to the next during the early stages of practice with decline in the rate of improvement as practice progresses. Towards the latter stage of the experiment while the decrease in reaction time diminishes with further practice, improvement is never completely eliminated (Anderson, 1995; Speelman & Maybery, 1998). When these typical results are plotted on log-log axes a linear relationship between log reaction time and log practice is observed. This indicates that improvements in performance time are a power function of increased practice on a task (Anderson, 1982). The fact that this pattern of results has been observed in just about all tasks where practice leads to improvement in performance time, has led to this phenomenon being referred to as the *Power Law of Practice* (Neves & Anderson, 1981; Newell & Rosenbloom, 1981; Pirolli & Anderson, 1985).

While a frequent belief is that well-practiced skills do not decay with disuse, research has demonstrated this may be clouded by the fact that the amount of forgetting appears relatively small in comparison to the amount of improvement with practice (Anderson, 1992; Loftus, 1985). Some research has demonstrated that any decline in automatic performance over time appears to follow a power function (Anderson & Schooler, 1991; Grant & Logan, 1993).

The ACT* Theory

Anderson's ACT* theory (1982, 1987, 1992) is a procedural model of skill acquisition which describes skill acquisition as a process of refining and strengthening procedures necessary for performing tasks. There are two key assumptions underpinning the ACT* theory: (1) *declarative knowledge* (knowledge of facts) differs qualitatively from *procedural knowledge* (knowledge implicit in procedures and actions); and (2) *production rules* are the units of procedural knowledge. The declarative knowledge about a task, such as instructions about how to perform, is conceptualized as fact statements. In this form knowledge is flexible in its application. When the individual has converted the declarative knowledge into procedural form, the knowledge becomes implicit and performance may appear automatic (Anderson, 1982, 1987, 1992).

According to the ACT* theory all cognitive behaviour is controlled by production rules, or productions. Productions are conceptualized as 'if-then' statements or 'condition-action' pairs (e.g., if the traffic light is red then stop). ACT* proposes that practice leads to the refinement of productions such that they become more specific to the situation in which they are executed, leading to skilled behaviour (Anderson, 1982, 1987, 1992).

The three stages of skill acquisition outlined by Fitts' (1964) are encompassed in the ACT* theory as three relevant learning processes. According to ACT*, in the first stage, Fitts' *cognitive phase*, general productions and weak problem solving methods are used to interpret and encode knowledge in its declarative form. Anderson terms this first stage as the *declarative stage*. Anderson views Fitts' intermediate phase, the *associative phase*, as the process of transforming declarative knowledge

into procedural knowledge in the form of a production rules, referring to this gradual process as *knowledge compilation*. Fitts *autonomous stage*, is referred to as the *procedural stage* in ACT* theory. During this stage production rules, directly incorporating domain specific knowledge, are strengthened and applied with increasing efficiency (Anderson, 1982, 1987).

ACT* accounts for improved performance in two ways. Firstly, *compilation* transforms declarative knowledge into procedural knowledge and so leads to a reduction in the demands on working memory. Secondly, a *strengthening* process speeds up the execution of individual productions (Anderson, 1982, 1987).

Anderson further divides the compilation process into two sub-processes, *proceduralisation* and *composition*. The process of proceduralisation involves integrating task relevant information into a specific production rule rather than retrieving it from otherwise general productions held in working memory. It occurs when a production's circumstance matches a long-term memory structure that has been retrieved in working memory. While the domain in which the production can be applied is subsequently restricted, proceduralisation reduces the necessity for enforced rehearsal of the declarative knowledge in working memory (Anderson, 1982, 1987, 1992).

Composition refers to the process by which a single specific production is created by efficiently combining two or more productions, after the initial series of productions have been executed a number of times. In order to develop a single, more efficient production, the conditions of the early productions are collapsed to form the condition component of the new composed production. The single production rule eliminates the need to retrieve declarative instructions and performs the action in a single step that previously took several steps. The initial productions are collapsed in

such a manner that their sequence and overall aim are not altered, to ensure that the new production achieves the same purpose (Anderson, 1982, 1987). Consider the following example from Speelman and Maybery (1998), which outlines the set of productions used to solve the x in an algebraic formula $a = x + c$:

IF	the goal is to solve for x in equation of the form $a = x + c$	
THEN	set as subgoal to isolate x on RHS of equation	(1)

IF	goal is to isolate x on RHS of equation	
THEN	set as subgoal to eliminate c from RHS of equation	(2)

IF	goal is to eliminate c from RHS of equation	
THEN	add -c to both sides of the equation	(3)

IF goal is to solve for x in equation and x has been isolated on RHS
of equation

THEN LHS of equation is solution for x (4)

After the rules have been executed a number of times, Productions 2 and 3 will collapse as a result of the composition process into:

IF goal is to isolate x on RHS of equation

THEN add $-c$ to both sides of the equation (5)

Continued practice will result in Productions 1,5 and 4 being composed into a more efficient form:

IF the goal is to solve for x in equation of the form $a = x + c$
 THEN then subtract c from a and result is solution (6)

In this way the process of compilation has collapsed several productions to create one production that performs the task in one step. However, as the task is now performed in fewer, more discrete steps, the contents of working memory are not updated as often throughout the task. With extended practice, knowledge of earlier productions is no longer accessible to verbal report and is unable to serve as a clue to how the task was performed. This is because the earlier declarative information has been transformed into the condition-action pairs of the production rules. The individual performing the task can only recall the initial and the final productions of performance as these are the products that appear in working memory (Anderson, 1987).

Formation of production rules by composition and proceduralisation occurs in a hierarchical manner, which reflects the hierarchical goal structure of the task. Both processes capitalize on the consistencies of task performance. Composition maximizes consistencies in operations while proceduralisation maximizes the consistencies in information acted upon. However, Anderson (1982, 1987) proposes that the original productions are not eliminated by the restructuring processes of composition and proceduralisation, suggesting the co-existence of the original and the new productions. In this way two or more productions may apply to a specific condition. In the event of competition between two productions the most specific

production prevails. In this way the ACT* theory predicts that practice can result in both general and specific skills being developed, with general skills those that can be applied in response to different stimuli, while specific skills are restricted to particular stimuli only.

The second learning process in ACT* involves strengthening the production rules to bring about a quantitative improvement in performance. The speed by which a production can be applied is determined by the strength of its memory trace or associative bond. Dependent upon feedback, the strengthening process ensures that each time a production rule is successfully applied, it accumulates strength. Production rules lose strength with each unsuccessful application and with lack of use (Anderson, 1982, 1987). Thus practice leads to repeated successful execution of productions which increases their strength, resulting in faster, more reliable execution.

In comparison to composition and proceduralisation, strengthening does not alter the structure of the production. Subsequently, strengthening produces a much less rapid improvement. As the asymptote of the learning curve is approached, composition and proceduralisation are complete and the strengthening process has the strongest influence over the rate of skill acquisition (Anderson, 1982). As the strengthening mechanism produces less rapid improvement with each subsequent encounter with the stimulus, the strengthening process can account for the flatness of the power function curve noted as the asymptote is reached. By combining the indefinite yet decreasing marginal benefit from the strengthening process, with the rapid speed-up noted with the earlier two processes, where improvement occurs primarily in the early trials, the ACT* theory (1982, 1987, 1992) is able to account for the Power Law of Learning.

The Instance Theory of Automisation

Logan's Instance Theory of Automisation (1988, 1990) proposes that skilled performance is reliant on the retrieval of domain specific knowledge from memory of past solutions. According to Logan (1988, 1990), in the initial stages of skill acquisition, the individual relies on the execution of a general algorithm to generate a conscious solution to any novel stimuli. Each time the algorithm is executed the solution is stored in episodic memory, as an *instance*. These instances are stimulus-specific and are retrieved on subsequent encounters with the stimulus. Automaticity is achieved when the control of performance moves from algorithmic computation, noted in early practice, to single step memory retrieval, noted late in practice (Logan, 1988, 1990; Logan & Klapp, 1991).

Central to the Instance Theory are three main assumptions, *obligatory encoding*, *obligatory retrieval* and *instance representation*. *Obligatory encoding* means that attention to an item or event results in unavoidable encoding of the item or the event in memory. The quality of the stored memory is dependent on the conditions of attention. The second assumption of *obligatory retrieval* states that attention to an item or event is sufficient to activate retrieval from memory of whatever information has been stored about the stimulus in the past. Memory retrieval may not always be successful, but it is attempted regardless of intention. Logan (1988) links the acts of encoding and retrieval, claiming that the same act of attention to an item or event can provoke either or both processes. The final assumption, *instance representation*, proposes that each episode or encounter with a stimulus is encoded, stored and retrieved separately in memory as an instance, even if it is

identical to a previous episode (Logan, 1988). Thus Logan views automatic processing as fast and effortless.

Prior to reaching the point of automaticity, performance may be automatic on some trials but not on others (Logan, 1988). Logan (1988) describes the skill acquisition process using the metaphor of a race between the execution of a general algorithm and the retrieval of instances. The larger the number of instances stored in memory, the greater the likelihood that one will be retrieved before the algorithm has been completed. In this way practice on a task can be seen to provide additional instances readily available in memory, rather than a qualitative improvement in the strength of the memory. The Instance theory states that instances pertaining to given stimuli may fall along a distribution of retrieval times. Logan has not specified the exact nature of these memory traces and what properties or conditions make one instance faster than another, although he appears to imply that chance is involved (Greig & Spelman, in press). The focus is on having the memory traces available, how they got there is less important (Logan & Klapp, 1991).

The Instance theory can account for the Power Law of Learning by virtue of the race between the execution of an algorithm and the retrieval of instances (Logan, 1988, 1990). Extended practice adds more instances to memory, increasing the likelihood that instances will be available that can be retrieved in less time than is necessary for the algorithm to be executed. While performance may improve indefinitely, the greater the number of instances, the less likely it is that any new instances will be significantly faster than the already 'fast' ones (Logan, 1990; Logan & Klapp, 1991). Thus performance improves as a function of the number of presentations of a particular stimulus (Logan, 1988, 1990). The relationship between the size of the distribution and value of extreme scores found within the distribution

results in the speed-up and the negative acceleration that are characteristic of a power function (Logan, 1990; Newell & Rosenbloom, 1981).

Transfer

ACT* and the Instance theory make different predictions regarding the transfer of skills. Transfer can be defined as the extent to which skills acquired during performance of one task can influence performance on a different yet similar task (Kramer, Stayer, & Buckley, 1990). Typically transfer can be one of three types: (1) *positive transfer*, where previous experience enhances performance on a new task; (2) *negative transfer*, where previous experience impedes performance on a new task and; (3) *zero transfer*, where previous experience has no influence on performance of a new task. The present study is primarily concerned with the potential for positive transfer between tasks, focusing on the individual's capacity to use skills learnt in one domain to aid in performance and the subsequent acquisition of skills in another domain.

Transfer: Empirical Evidence

Research as to the nature of skill acquisition and the amount of transfer observed between two tasks is divided. Some researchers claim skills are general, while others report skills are specific. The majority of the literature supports the general theories of skill acquisition, which state that the amount of transfer between two tasks is dependent upon the number of shared elements between tasks. The ACT* theory is one such theory. It proposes that skilled knowledge is abstract in nature and therefore can be applied beyond the training environment (Anderson, 1982, 1983,

1987). Empirical evidence consistent with the development of general skills has been reported by Schneider et al. (1984), who identified a degree of transfer on perceptual tasks, Anderson (1987) who demonstrated transfer of programming skills, and Carlson, Khoo, Yare and Schneider (1990), who demonstrated that subjects could transfer their skill of troubleshooting with simulated problems in electronic circuits. In each example, performance on the second task was facilitated by knowledge gained from learning the first task. Transfer has also been found in lexical decision tasks (Kirsner & Speelman, 1993, 1996), syllogistic reasoning (Speelman & Kirsner, 1997), letter search (Schneider & Fisk, 1984) and social judgement (Smith & Lerner, 1986).

In contrast, a smaller number of researchers report that skills are highly specific in nature, constrained to the context in which they are acquired (Byrne, 1984; Logan, 1988, 1990; Rickard, 1997). Specific skills are predicted by the Instance theory because the theory states that there should be no transfer between similar tasks. As each stimulus is encountered, highly specific information about the event is processed. When a new problem is presented, knowledge from prior experiences plays no role in assisting the individual to find a solution, even when these earlier experiences bear a strong similarity to the problem at hand (Logan, 1988, 1990).

An experiment by Logan & Klapp (1991) provides empirical support for the development of specific skills. The experiment involved both training and transfer phases in which participants performed an alphabet arithmetic task. Participants were asked to solve alphabet equations such as $A + 2 = C$, stating whether each statement was true or false. One strategy used to perform the task was to count forward through the alphabet, (e.g., A) by the given number of letters (e.g., 2) before comparing the resultant letter with the presented answer (e.g., C). In the training phase of the

experiment participants were presented with problems involving letters from one half of the alphabet. In the transfer phase participants were required to solve problems involving letters from the other half of the alphabet. The transfer of skills acquired during the training phase to the transfer task was measured by comparing the reaction times for the final training items against the reaction times for the initial transfer items. Reaction times on the transfer task were found to be significantly higher than reaction times in the last session of training. This result indicates that the skills participants acquired during training were highly specific. When a new set of items was presented in transfer, these skills could not be applied. Slower reaction times on the transfer task reflect the participant's need to learn new skills to perform the transfer task. Similar empirical support for the development of specific skills has been made in relation to reading tasks (Byrne, 1984; Byrne & Carroll, 1989) and word identification (Masson, 1986).

Skills have also been found to be both general and specific in some situations. One example particularly pertinent to the current study is an experiment by Greig and Speelman (in press). The Greig and Speelman experiment was divided into training and transfer phases. In the training phase participants were presented with an algebraic equation (e.g., $x^2 + 2y$), which they solved by substituting values for x and y (e.g., $x = 1$ and $y = 3$). Training contained several blocks of trials with the x and y values taken from a small fixed set of values. In the transfer phase participants evaluated the same equation, using a different set of values for x and y than those used in the training phase.

Results demonstrated firstly that participants' reaction time was much slower in the first block of trials of the transfer task than on the last block of trials of the training task. In addition reaction time in the first block of trials of the transfer task

was significantly faster than in the first block of trials in training (Greig and Speelman, in press). These findings indicate that practice on the training task was beneficial when the transfer task was presented. That is, participants performed the first trials of the transfer task faster than the first trials of the training task. This indicates that participants did not have to learn to perform the entire task again. Thus the skill they learnt in training was general to some extent. However, participants' initial slower performance on the transfer task compared to final performance on the training task indicated that while some transfer occurred it was not complete. That is, participants' performance was disrupted by the change of items, indicating that their skill was, to some extent, specific to the items experienced in training. Thus these results demonstrated that skills can be both general and specific.

Transfer: Theoretical Explanations

Early general theories of skill acquisition proposed that learning was based on the consistencies between tasks (e.g. Crossman, 1959; Thorndike & Woodworth, 1901, cited in Frensch, 1991). According to these theories, when variations of a similar task are encountered, performance is refined on the basis of commonalities between the task. Transfer is enhanced if the new task shares some of the common elements. According to ACT* the abstract nature of productions enables them to be applied to situations not previously encountered, provided the algorithm they exemplify is appropriate (Anderson, 1982, 1987). The amount of transfer between two tasks is therefore dependent on how well productions developed to perform one task can be executed to perform another. If the tasks are similar to each other it can be predicted that the amount of transfer will be high, although it will not be absolute.

Therefore transfer can be viewed as general in nature, based on common procedural knowledge between similar tasks, with this assertion supported by empirical literature (e.g., Corbett & Anderson, 1992; Frensch, 1990; Kirsner & Speelman, 1996; Singley & Anderson, 1989).

ACT* can also account for the findings of Greig and Speelman (in press) that skills can be both general and specific in the one situation. According to ACT* participants in the Greig and Speelman experiment would initially have developed a series of general productions for the items presented in the training phase. ACT* would predict that by presenting the x and y pairs repeatedly during training, participants developed a set of specific productions by the end of training to that set of x and y values. These specific productions would be strengthened and become faster than the general productions, as they involve fewer processing steps. According to ACT*, the presentation of the new set of items in the transfer phase would result in the specific productions no longer being executed successfully. This in turn would lead to a disruption in performance, evidenced as slower reaction times on the initial transfer items. As participants would have retained the general productions acquired during training though, ACT* predicts that their performance on the initial transfer items would be faster than their performance during the initial training items.

The Instance theory (Logan, 1988, 1990) predicts no transfer between similar tasks. When faced with a new task, the individual is unable to recall an instance because they have had no preceding contact with that specific problem. Their performance on the new task is therefore not facilitated by prior practice on a similar task. Logan maintains that skilled behaviour is specific to previous experience (Logan, 1988, 1990). If performance conditions are altered, no transfer can occur, and so performance should return to pre-practice levels (Speelman & Kirsner, 1997).

When a task has been encountered earlier, performance on a second occasion is potentially as good as that observed originally.

The Current Study

The main aim of the present research was to determine the effect of the amount of practice on the specificity of skill acquisition and transfer of a skill. The experimental design allowed for comparison of the accounts of skill acquisition outlined by the ACT* Theory and the Instance theory. In particular, the experiment tested the respective predictions of the two theories regarding the effects of differing amounts of practice on the amount of transfer observed between similar yet different versions of a task. It was hypothesised that (a) training would lead to the development of both general and specific skills as evidenced by partial transfer of skills to a different yet similar task and (b) that greater amounts of training would lead to greater specificity evidenced as greater disruption in performance from the training to the transfer task.

The current experiment was divided into training and transfer phases. In both phases, participants solved a similar algebraic equation, $\frac{(x^2 - y)}{2}$, substituting values for x and y (i.e., $x = 5$ and $y = 9$) into the equation. During training the values for the x and y pairs were randomly sampled from a small, fixed set. The amount of training was manipulated across three experimental groups. Participants were required to solve the same equation during transfer using a different set of values for the x and y pairs.

The algorithm task involved a similar algebraic formula to the one used by Greig and Speelman (in press). This in turn was viewed as similar to Logan's alphabet

arithmetic task (Logan & Klapp, 1991), with the relationship between the stimulus (i.e., formula and the x and y pairs) and the appropriate response (i.e., solution to the equation) considered to be comparable to the stimulus-response relationship in the alphabet arithmetic task. The repetitious nature of the task enabled participants to apply the same arithmetic operations for each problem thus becoming increasingly fluent at the task. With the increasing fluency on the experimental task, participants could be expected to externally recognise the problem and remember the solution rather than need to generate the answer (i.e., $A + 2 = C$, "Yes").

The Greig and Speelman experiment (in press) was such that the same equation was presented in both the training and the transfer phase, applying a different set of x and y values in each phase. This design meant there was the potential for participants to acquire both general and specific skills. In the present study by manipulating the amount of practice across experimental conditions, participants retained the potential to acquire both general and specific skills. However, the amount of one type of skill (i.e., specific skills) they acquired was potentially different to the amount of the other type of skill (i.e., general skills) they acquired as a function of how much practice they received in the training phase.

The experiment was designed such that the same equation was presented in both phases, with different x and y values in each phase. As a result performance on the presentation of the second set of items would reflect the general or specific nature of the skills acquired during the training phase. The ACT* theory (1982; 1987) would predict that the strategy learned during the training phase could be used to solve the equation in the transfer phase. As a result performance on the second set of items would match performance on the first set of items, indicating complete transfer. Conversely, specific theories, such as the Instance theory, would predict that

performance in the second phase would not be influenced by performance in the first phase, as different sets of items are presented in each phase. Thus zero transfer would be evident. If participants are faster at the task in the second phase than they were in the first phase of the experiment, the improved performance would suggest that partial transfer of skills had occurred. This would indicate that both general and specific skills had been acquired. The acquired skill would not be entirely restricted to the specific task presented in training, but nor would it totally generalisable to the new task presented in transfer. This in turn would support the findings of Greig and Speelman (in press).

ACT* (Anderson, 1992) states that specific productions are more likely to develop as the amount of practice on the training items increases. Thus in the current experiment as the amount of practice with one set of items increases prior to the presentation of the transfer items, an increase in the amount of disruption to performance should occur on the transfer task. The Instance theory however, would predict that increases in the amount of practice would have no effect on the amount of disruption evidenced on the transfer task. Increased practice would only increase the number of instances in memory for the training task, not increase the range of potential instances to be retrieved in transfer. Transfer should therefore be zero, regardless of amount of practice during training with performance on the transfer task returning to pre-practice levels.

Method

Participants

Non probability sampling was used to select a convenience sample of undergraduate students from Edith Cowan University, Joondalup Campus. Participants were recruited through announcements during lectures and with notices placed on student notice boards. They were given an information letter briefly outlining the experimental task, and a consent form, which they completed if they were willing to participate in the study (see Appendix A).

A total of 42 students volunteered for and completed the experiment, of which 19 were male and 23 were female. The mean age of participants was 28.5 years; participant's age range was between 18 and 50 years. A further seven students participated in the experiment, however they were excluded from the study due to either failure to complete both phases of the experiment or for poor performance (i.e., mean accuracy less than 50% and reaction times more than three standard deviations from the mean).

Participants were randomly assigned to equal sized groups which represented the three experimental conditions, resulting in three groups of 14.

Participants were assured that their participation in the experiment was not a part or condition of their courses. They were informed that their participation was voluntary and they were free to withdraw at any stage. Participants were informed that their responses would remain confidential and individual performance would not be identifiable from reports of the results.

Each participant was paid \$5 for their time, irrespective of which experimental condition they were in and whether they completed the experiment or not.

Design

The study involved one independent variable, the amount of time spent practicing the task in the training phase, and two dependent variables, accuracy and reaction time measured in milliseconds.

The experiment was divided into a training phase and a transfer phase. The training phase included the three levels of the independent variable. The amount of practice was manipulated such that the first group received one training session before being presented with the transfer task, the second group received two training sessions and the third group received three training sessions before being presented with the transfer task. Thus training condition was a between-subjects variable.

Apparatus

Individual presentation of the instructions, the experimental task, recording of responses and feedback was controlled by HyperCard software. The program was run on two Apple Macintosh computers, a LC and a Power Macintosh 7200.

Procedure

Testing was conducted individually in a computer laboratory in the Psychology department. Prior to undertaking the experimental task, participants were

presented with a set of instructions and 2 practice trials. The experimenter was present during the practice trials, to provide feedback and assistance, but once the experimental trials had begun the participant worked independently.

The algorithm and answer options were presented on the computer screen, where the participants' task was to decide if the answer was odd or even. They were instructed to record their response by clicking on the appropriate region of the screen with the computer mouse, using their dominant hand to manipulate the mouse. Participants were instructed to respond as quickly as possible without foregoing accuracy.

Participants were required to solve the equation $\frac{x^2 - y}{2} = A$, by substituting values for x and y into the equation. They were instructed that if A was an even number then they should click on one area of the screen and if A was an odd number then they should click onto a second designated area of the screen (see Figure 1). The same algebraic equation was presented in both the training and transfer phases of the experiment.

$\frac{x^2 - y}{2} = A$	
$x = 5$	$y = 9$
<div style="border: 1px solid black; padding: 5px; display: inline-block;"> If A = odd Click here </div>	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> If A = even Click here </div>

Figure 1. An example of the algebraic task, as shown to participants on the computer screen.

One set of 8 pairs of values for x and y was used during training, with a different set of 8 pairs of x and y values presented in the transfer phase (see Table 1). The item sets were constructed to be of approximately equal difficulty. The items presented in the training phase and the transfer phase were counterbalanced across participants so that for half of the participants Set 1 was presented during training, and for the other half of the participants Set 2 was presented during training. To control for any potential difference between the operating speed of the two computers, the presentation of item sets were further counterbalanced between the two computers, across each of the experimental conditions. This was achieved by alternating the order of presentation of item sets across each condition to ensure that half the participants on each computer received Set 1 during training, while the other half received Set 2. For example, the first participant in condition one, using the LC computer, was presented with the items in Set 1 during training while the second participant was presented with Set 2 during training. The first participant in the same condition, using the Power Macintosh, was presented with the items in Set 2 during training with the second participant presented with Set 1.

Table 1

Values for x and y in the Training and Transfer Phases of the Experiment.

Set 1				Set 2			
x	y	A	Response	x	y	A	Response
5	9	8	even	6	10	13	odd
5	11	7	odd	6	12	12	even
5	13	6	even	6	14	11	odd
5	15	5	odd	6	16	10	even
8	2	31	odd	7	1	24	even
8	4	30	even	7	3	23	odd
8	6	29	odd	7	5	22	even
8	8	28	even	7	7	21	odd

In a single training phase, 320 items were presented in 40 blocks of 8. Each block of 8 trials consisted of the 8 items of a set presented in random order. The presentation order was such that each pair of values for x and y were encountered once per block. There was, however, the possibility that pairs were presented twice in a row, in the last trial of one block and the first trial of the next block. Participants were not made aware of the block structure underlying the trial sequence.

For the groups receiving repeated training, the initial set of items was repeated in each subsequent training phase. This meant that group one had only one training session and were presented with the training items once (i.e., 320 trials), while group two performed the training items in two training sessions (i.e., 640 trials). The third group received three training session in which they were presented with the training items three times (i.e., 960 trials).

In the transfer phase of the experiment the task involved participants solving the same equation presented during training. Using an identical method of testing, a further 320 trials were presented. However, a second set of items with different x and y pairs was used. Maintaining the same block structure used in the training phase, item pairs were presented within blocks of eight trials where the order of presentation within the block was random.

Participants were not made aware of changes to the values for x and y between the training phase and the transfer phase. Likewise participants who received repeated training were not informed that the values for x and y would remain the same. However, there was a short break of 5 to 10 minutes between each level of the training phase, for groups 2 and 3 and again between the training phase and the transfer phase, for all groups. During this time the experimenter restarted the computer program to repeat the training task or to begin the transfer task. It was

explained to the participants that the experimental task was the same as in the previous phase and that they should respond in the same manner.

In all three experimental conditions, training and transfer tasks were presented in one sitting. A single training phase and transfer phase took up to one hour to complete. Repeated training phases and the transfer phase required between one and half to two hours.

Feedback concerning the correctness of a response was provided immediately following each item on the computer screen and participants were debriefed upon completion of the experiment.

Results

All data screening and data analysis procedures used the Statistical Package for the Social Sciences (SPSS), Version 7.5.

Data Screening

Data was screened for each training session (6 in total across the three training conditions) and for each transfer session (3 in total) separately prior to analysis. The accuracy and reaction time values were examined separately. As no significant outliers were found and normality was deemed satisfactory, the data was found to be appropriate for the intended analyses.

Accuracy: Training and Transfer

The analyses of the accuracy scores included three split-plot analyses of variance (SPANOVA). The analyses revealed there were no significant differences between the groups in accuracy scores during training or during transfer. Participants demonstrated a high level of accuracy in all phases of the experiment. During the initial training phase, the average mean accuracy rate for all groups was 93.5%. Average mean accuracy rate during the final training phase of the experiment increased marginally to 96%. A slightly lower mean accuracy rate for all groups of 91% was observed during the transfer phase. In all phases of the experiment, the participants' accuracy improved as more blocks of items were presented as indicated in the results of the SPANOVA's.

The first SPANOVA compared the accuracy scores of the three groups in the first 40 blocks of trials of the experiment. The absence of a statistical difference on the between-subjects analysis, $F(2,39) = 0.537$, $p > 0.05$, indicated that all groups performed at a similar level during their initial training phase. The within-subjects analysis demonstrated a significant improvement in participant's accuracy from one block of trials to another, $F(39,1521) = 6.929$, $p = 0.00$. The interaction between condition and block was not significant, $F(78,1521) = 1.236$, $p > 0.05$.

A second SPANOVA was conducted on the accuracy scores in the last 40 blocks of trials during the training phase of the experiment. There was a statistically significant effect of block; $F(2,39) = 2.337$, $p = 0.00$. This result indicated that participants' accuracy continued to improve as more items were presented. There was no statistically significant effect of condition, $F(39,1521) = 0.74$, $p > 0.05$. The interaction between block and training group was also not significant; $F(78,1521) = 1.283$, $p > 0.05$.

The final SPANOVA on accuracy compared the three groups' performance during the transfer phase of the experiment. There was a significant main effect for presentation block, $F(39,1521) = 11.419$, $p = 0.00$, indicating accuracy improved across trial blocks. The absence of a statistical difference on the between-subjects analysis, $F(2,39) = 0.373$, $p > 0.05$, demonstrated that all groups performed at a similar level during transfer. The interaction between condition and block was not significant, $F(78,1521) = 0.455$, $p > 0.05$. Copies of the relevant output summary tables are included in Appendix B.

Reaction Time

Training

Two split-plot analyses of variance (SPANOVA) and a single one way analysis of variance (ANOVA) were conducted on the training data to compare performance of the three groups across different amounts of training. Performance, measured by mean reaction time (RT), was analysed in eight item blocks, with a single training application and the transfer phase each consisting of forty blocks. These reaction times are presented in Figure 2 for all conditions.

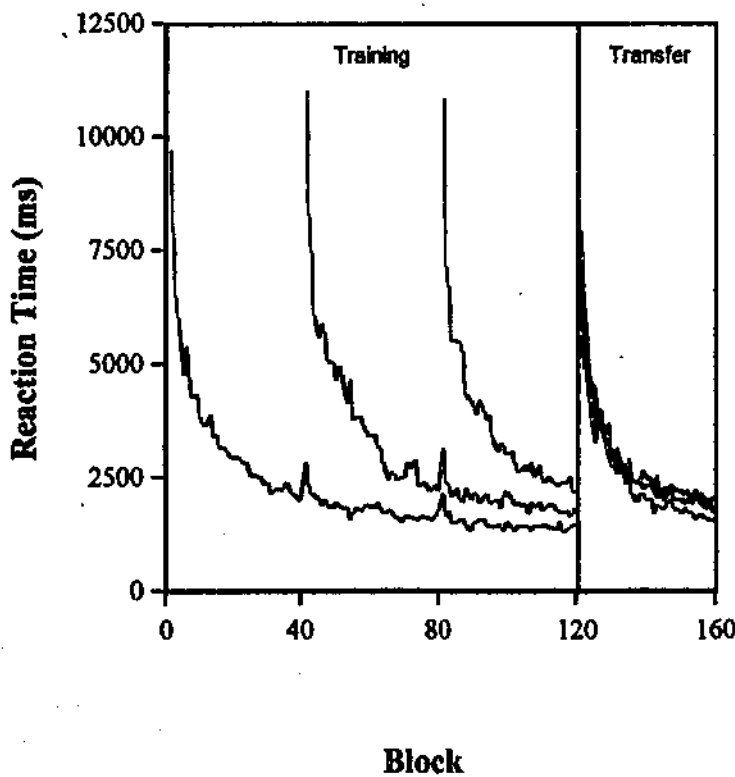


Figure 2. Mean reaction times during training and transfer for the three experimental conditions.

To determine whether the three groups were performing at a similar level after only one training session, a split-plot analysis of variance (SPANOVA) was

performed to compare their respective reaction times (RT) in the first 40 blocks of trials of the experiment. The absence of a statistical difference on the between-subjects analysis, $F(2,39) = 0.609$, $p > 0.05$, indicated that all groups performed at a similar level during their initial training phase. The within-subjects analysis demonstrated a significant reduction in participant's RT from one block to another; $F(39,1521) = 89.357$, $p = 0.00$. Participant's became faster at the task as more blocks of items were presented. The interaction between condition and block was not significant, $F(78,1521) = 0.631$, $p > 0.05$. These results are illustrated in Figure 2. Blocks 1 to 40 illustrates the initial training results for group 3, which received three training sessions. The initial training results for group 2, which had two training sessions, are illustrated in blocks 41 to 80. Blocks 81 to 120 illustrate the initial training results for group one, which had only one training session.

A second SPANOVA was performed to compare participant's RT in each condition in their respective final training session, to determine whether there was an effect of the different amounts of practice on performance. The SPANOVA indicated that there was a statistically significant effect of training group; $F(2,39) = 48.973$, $p = 0.00$. There was also a statistically significant effect of block, $F(39,1521) = 48.918$, $p = 0.00$. The interaction between block and training group was also significant; $F(78,1521) = 27.21$, $p = 0.00$. These results indicate that participants became faster at the task with practice during their final training trials. The interaction demonstrated that while improvement in performance was continuous throughout, for each condition, the amount of improvement was influenced by the amount of prior training each group had received. The group of participants that received one training session only showed rapid improvement across early trials but exhibited much less improvement during the later half of the final training phase. Participants in group

two and group three appeared to have ceased improving prior to the beginning of the final training phase, exhibiting minimal improvement in RT with further practice.

These results are illustrated in blocks 81-120 in Figure 2 for all three groups.

In order to further clarify the difference found between the three groups during the final training phase, a one way analysis of variance (ANOVA) was conducted on RT performance in the last block of items in the final training phase. The aim of this analysis was to determine whether there were differences in reaction time between the three groups just prior to the transfer phase but after most of the improvement had been achieved. The results of this analysis demonstrated that the groups continued to display significantly different RTs on the 40th block of item, $F(2,39) = 3.881$, $p = 0.029$. Tukey's post hoc pairwise comparisons indicated that individuals who received three training sessions performed significantly faster than those individuals who received only one training session. Copies of the relevant output summary tables are included in Appendix C.

Transfer

The comparison of the three groups' performance on the transfer task was conducted using a split-plot analysis of variance (SPANOVA). There was a significant main effect for presentation block, $F(39,1521) = 36.898$, $p = 0.00$, indicating performance improved across trial blocks. No significant interaction was found between block and training condition, $F(78,1521) = 0.492$, $p > 0.05$. There was also no effect of training condition on transfer performance, $F(2,39) = 0.248$, $p > 0.05$. This finding indicates that the amount of practice received during training did

not lead to group differentiation on transfer. These results are illustrated in blocks 121 to 160 in Figure 2.

To determine whether there were group differences in the amount of disruption to performance from training to transfer, a SPANOVA was performed on RTs in the last block of training and the first block of transfer. The within-subjects analysis revealed a significant main effect for presentation block, $F(1,39) = 75.613$, $p = 0.00$. The descriptive statistics in Table 2 illustrate that all groups recorded faster RT for the final training items than for initial transfer items. Post hoc comparisons performed using Tukey's HSD, indicated that the difference RT on initial training block items and RT on initial transfer block items was significant in all three groups.

Table 2

Comparison of Mean Reaction Time During Final Training Block Items and Initial Transfer Block Items.

Block	<u>Condition</u>					
	<u>1</u>		<u>2</u>		<u>3</u>	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
Last Training	2152	871	1786	633	1411	535
Initial Transfer	7833	2628	6733	2580	7710	6274

No significant interaction between item block and condition was found, $F(2,39) = 0.363$, $p > 0.05$. Results were not significant for the between-groups effect, $F(2,39) = 0.404$, $p > 0.05$. These results indicate that it was not possible to

differentiate the group's performance on initial transfer items as a function of the amount of training they received in the training phase.

A third SPANOVA was used to compare performance across groups between the first block of training and the first block of transfer. Results were significant for the main effect of block, $F(1,39) = 30.842$, $p = 0.00$. The descriptive statistics in Table 3 illustrate that all groups recorded slower RT for the initial training block compared to the initial transfer block. Tukey's post hoc comparisons indicated that the difference between RTs for the initial training block items and the initial transfer block items was significant in all three groups.

Table 3

Comparison of Mean Reaction Time During Initial Training Block Items and Initial Transfer Block Items.

Block	<u>Condition</u>					
	<u>1</u>		<u>2</u>		<u>3</u>	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
Initial Training	10808	4984	10960	5257	9680	4362
Initial Transfer	7833	2628	6733	2580	7710	6274

No significant interaction between item block and condition was found, $F(2,39) = 1.405$, $p > 0.05$. There was also no significant main effect of condition, $F(2,39) = 0.092$, $p > 0.05$. These results support previous findings that that it was not possible to differentiate the group's performance on initial transfer items as a function

of the amount of training they received in the training phase. Copies of the relevant output summary tables are included in Appendix D.

Power Functions

Power functions of the form $RT = bP^c$ (where P = number of blocks of practice) were fitted to the training data from all three conditions. The parameters of the power functions fitted to the training data are presented in Table 4. These power functions were then extrapolated into the training phase. Confidence intervals ($\alpha = 0.05$) were calculated for the transfer data to determine whether performance in the transfer phase constituted a significant deviation from the practice function observed in training. Transfer performance is considered to be complete if the extrapolated performance falls within the confidence limits. Transfer is considered less than complete if the extrapolated performance falls above the upper confidence limit. The power functions and confidence intervals, along with training and transfer RTs for each condition are illustrated in Figures 3, 4 and 5.

Table 4

Parameters of Power Functions of the Form $RT = bP^c$ Fitted to the Training Data.

	<u>Parameters</u>		<u>Goodness-of-fit</u>	
	<u>b</u>	<u>c</u>	<u>r^2</u>	<u>rmsd</u>
Training 1	10499.368	-0.416	0.996	239.8276
Training 2	11485.878	-0.426	0.993	285.2188
Training 3	10206.129	-0.427	0.996	157.9561

Figure 3 illustrates that participants who received a single training session were slower at the beginning of transfer than they were at the end of training. While their performance at the beginning of transfer is significantly faster than it was at the beginning of training, the figure indicates that participants took nine blocks of trials before their performance recovered to within the predicted range for completed transfer.

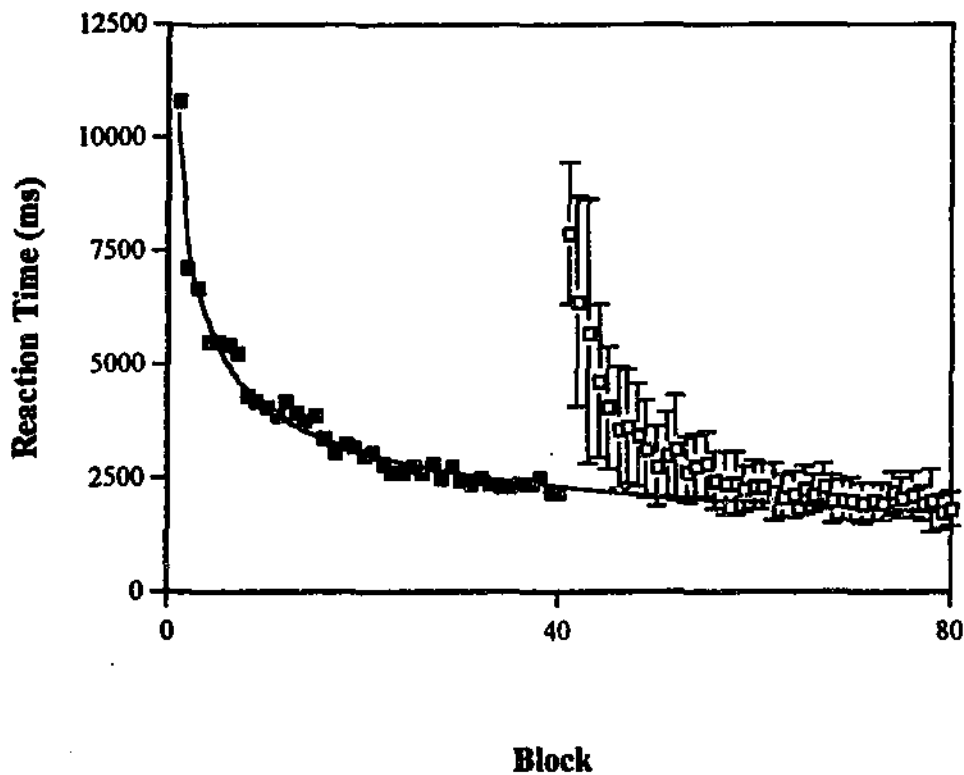


Figure 3. Mean reaction times during training(closed squares) and transfer(open squares) for participants receiving one training session. The line represents the best fit power function fitted to the training data (see Table 4 for parameters) The error bars represent confidence intervals ($\alpha = 0.05$).

Participants who received two training applications had slower RTs at the beginning of transfer in comparison to the RTs recorded at the end of training, as illustrated in Figure 4. The figure indicates that participants took twelve blocks of trials before their performance recovered to fall within the range of values predicted if transfer had been complete. However, it is noted that their performance at the beginning of transfer is significantly faster than it was at the beginning of training.

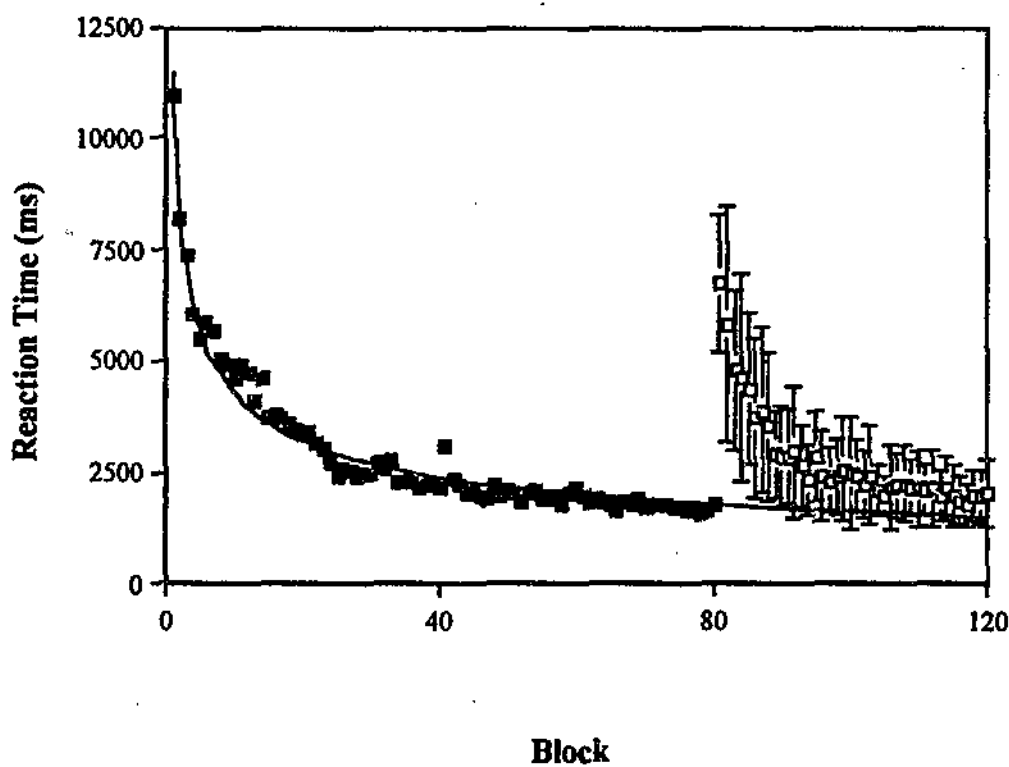


Figure 4. Mean reaction times during training(closed squares) and transfer(open squares) for participants receiving two training sessions. The line represents the best fit power function fitted to the training data (see Table 4 for parameters) The error bars represent confidence intervals ($\alpha = 0.05$).

For participants who received three training applications, Figure 5 illustrates that these individuals also experienced slower RTs at the beginning of transfer in comparison to the RTs recorded at the end of training. It is noted that their performance at the beginning of transfer is significantly faster than it was at the

beginning of training. The figure indicates that participants took twenty blocks of trials before their performance recovered to fall within the range of predicted values for complete transfer.

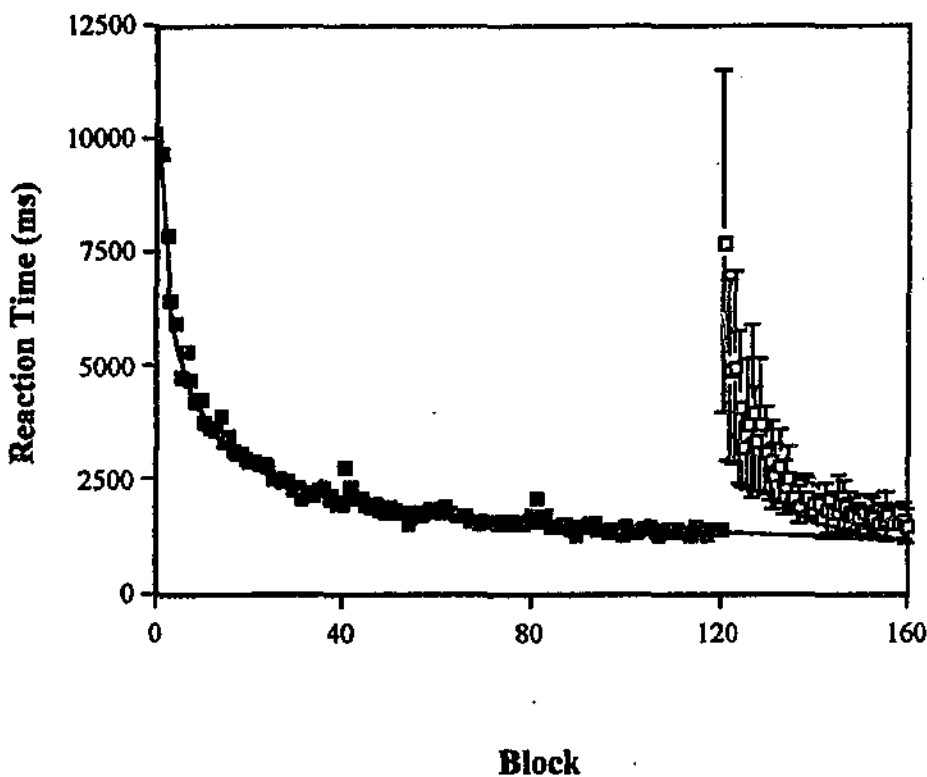


Figure 5. Mean reaction times during training(closed squares) and transfer(open squares) for participants receiving three training sessions. The line represents the best fit power function fitted to the training data (see Table 4. for parameters) The error bars represent confidence intervals ($\alpha = 0.05$).

Discussion

In this experiment varying support was observed for the initial predictions that (a) training would lead to the development of both general and specific skills as evidenced by partial transfer of skills to a different yet similar task, and (b) that greater amounts of training will lead to greater specificity evidenced as greater disruption in performance from the training to the transfer task.

From the analyses conducted on the training data it was demonstrated that after one training session, all the groups performed at a similar level. A significant difference was found between the groups at the end of training, with the group that received extended practice on the training task performing faster than participants in the other groups. The latter result suggests that the extra training allowed those participants to refine their skills and subsequently perform the task at a faster rate. Both results indicate that the improved performance was directly related to the amount of practice participants received, not differences in ability.

All participants recorded significantly faster reaction times for the initial transfer items compared to the reaction times they recorded for the initial training items. In isolation, this result indicates that positive transfer occurred. That is, training was beneficial to all participants when they came to perform the transfer task, irrespective of the training condition they were assigned to. However further analysis of the data indicated that transfer was not complete, with participants' reaction time for initial transfer items significantly slower than their reaction time on the final training items. If transfer had been complete, performance at the beginning of transfer would have been at least as fast as observed at the end of training. Furthermore if transfer was complete, power functions describing training performance could be

used to predict performance on the transfer task (Greig & Speelman, in press; Speelman, 1991; Speelman & Kirsner, 1993). In this experiment the training power function analyses underestimated reaction times in each of the three conditions. Thus the finding of partial positive transfer from the training task to the transfer task is indicated by all participants recording significantly faster reaction times for the initial transfer items compared to the reaction times they recorded for the initial training items and significantly slower reaction times for initial transfer items than their reaction times for final training items. Thus it can be concluded that both general and specific skills were developed during training. Therefore these findings directly support the first hypothesis that training would lead to the development of both general and specific skills.

The results are problematic for specific theories of skill acquisition, as specific theories of skill acquisition are unable to account for the display of partial positive transfer. In the case of the Instance theory, Logan (1988, 1990) predicts that zero transfer would be observed in this experimental situation. Initially general algorithms would be performed to solve the training task. An instance representing the solution to the equation with the initial set of x and y values would be stored in memory each time a trial was encountered. Throughout the training phase, on each trial a race would occur between the execution of the general algorithm and the retrieval of a suitable instance from memory, with the winner controlling processing on that trial. With sufficient practice, specific instances would be retrieved faster than the execution of the algorithm. Ultimately, performance would come to be dominated by a single-step retrieval of a solution on each trial, rather than the generation of a solution. When the x and y pairs were changed in the transfer phase of this experiment, participants would have to revert to computation of the general algorithm

as they would have no relevant instances stored in memory to match the new set of items. In the context of Logan's (1988) claims that the algorithm does not improve with practice, the extended practice in this experiment would only increase the number of instances in memory for the training task, not increase the range of potential instances to be retrieved in transfer. Experience would only be beneficial during transfer if the same values for x and y had been experienced previously.

In this experiment the values for x and y were altered for the transfer task, therefore Logan would predict transfer should be zero. That is, performance on the transfer task should have returned to pre-practice levels. The findings of partial positive transfer in this experiment are in direct conflict with Logan's theory.

General theories of skill acquisition are capable of providing a more comprehensive explanation for the partial positive transfer observed in this experiment. In particular the ACT* theory (Anderson, 1982, 1987) can account for the acquisition of both general and specific skills in certain situations. As a result ACT* provides a superior account of the findings of this experiment.

According to ACT*, in this experiment participants would have developed early in the training phase a set of general productions which they would apply to help them solve the algebraic equation. The general nature of these productions would enable them to be applied to any set of x and y values that were to be substituted into the equation. As each x and y pair was encountered repeatedly in the training phase of this experiment, ACT* would predict that additional productions would be developed that would be specific to the set of x and y values presented in the training phase. In the final blocks of training each of the specific productions would be more likely than the general productions to be executed in direct response to a particular x and y pair. These specific productions would require far fewer processing steps than the general

set of productions, used in the initial stages of the training phase and so would also lead to faster performance. Furthermore, as each of these specific productions was strengthened they would become faster still. When participants were confronted with a new set of x and y values in the transfer phase, however, the specific productions would no longer be beneficial to help them solve the equation. As a result performance would be significantly slower on the initial transfer items than for the items presented at the end of training. However, according to the ACT* theory, participants would retain the ability to apply the general productions they acquired early in the training phase, even to the new set of values for x and y presented in the transfer phase. This would account for the finding that participants' performance on the initial transfer items was significantly faster than their performance on the initial training items.

The results of the comparisons of the three groups' performance on the transfer task were equivocal. Some of the analyses indicated that the amount of practice received during training did not lead to differentiation between the groups on performance during initial transfer. It was hypothesised that greater amounts of training would lead to greater specificity, which would result in greater disruption in performance on the subsequent transfer task. While it was difficult to ascertain if this was the case from the initial analysis of the transfer data, the power function analyses and the comparison of reaction times for final training items against reaction times for initial transfer items provided greater support for the hypothesis. The results of these analyses suggested that the greatest amount of disruption was in fact experienced by the group of participants who received the most training when they were presented with the transfer task.

As noted earlier all groups performed better on the initial transfer items than they did on their respective initial training items. It was also noted that there was a significant difference between the groups at the end of training, with the group that received extended practice on the training task having the fastest reaction times at the end of training. This improved performance was directly related to the amount of practice participants received prior to the transfer task. As the specific skills developed in training were not of any additional benefit on the transfer task, the value of the extra practice in training needs further clarification.

The power function analyses and the comparison of the final transfer and initial training reaction times indicate that the more practice an individual received on the training task the greater the amount of disruption they experienced when presented with the transfer task. In the case of those participants who received three sessions of training, when they were presented with the transfer task they experienced much greater slowing in reaction times than participants in either of the other two groups. Furthermore, it took much longer for their performance to return to the same level they recorded during the final training trials. In short, the group that received the most training had the fastest reaction times at the end of training and, upon presentation of new values for x and y in the transfer task experienced higher level of disruption to their performance.

As has already been stated, the Instance theory (Logan, 1988, 1990) predicts that zero transfer would be observed in this experimental situation. Since Logan's Instance theory (1988, 1990) is unable to account for the partial positive transfer observed in all three conditions in this experiment, the theory is also unable to offer any satisfactory explanation to account for the difference in the amount of disruption in performance caused by the change in the x and y values that was associated with

the amount of training. In contrast, the ACT* theory (Anderson, 1982, 1987, 1992) is more able to account for the different levels of disruption in performance evidenced upon presentation of the transfer task in this experiment.

According to ACT*, participants would begin the training phase of the experiment using a set of general productions, which could be applied to any set of x and y values substituted into the equation. Furthermore, ACT* predicts that the repeated presentation of each x and y pair in the training phase, would lead to the development and strengthening of specific productions. As productions were strengthened they would be performed at a faster rate, with each specific production involving far fewer processing steps than the general set of productions. Productions used at the end of training would be highly specific to the set of x and y values presented during the training phase. In the case of those participants who received larger amounts of training (i.e., three training sessions) prior to the presentation of the transfer task, the likelihood is that as practice increases, specific skills get more opportunity to be applied and become faster than general skills. Hence, the high practice group were more likely to have developed very fast specific skills at the end of training than the low practice group. Therefore, participants with one training application would be using both general and specific skills to solve the equation immediately prior to the presentation of the training block, whereas the group that received the most training would be relying on their faster specific skills at the end of training.

The partial positive transfer of skills demonstrated by all groups indicates that all participants were able to use some general skills to solve the equation when they were presented with new values for x and y in the transfer phase. Furthermore, given that all groups performed the initial transfer items with similar speeds suggest that all

had general skills that were developed to the same extent. This implies for the participants who received the largest amount of training, these general skills appear to have maintained their strength despite being used less frequently during the final training session. Therefore, the increased disruption experienced by these individuals between the final training items and the initial transfer items appears to be due to the development of faster specific skills to the items presented in training, which in turn improved performance on the training items but were of no benefit when the values for x and y were changed in the transfer phase. This was evidenced by a greater amount of slowing in their reaction time between final training items and initial transfer items, with high practice participants taking longer to return to their pre transfer level of performance. In this experiment the ACT* theory provides a more comprehensive explanation for the prediction and findings that greater amounts of training will lead to greater specificity as evidenced by greater disruption in performance from the training to the transfer task.

Future Research Implications

The question remains as to why was there no significant difference between the three groups on the initial transfer items and under what conditions, if any, it is possible to elicit a difference in performance between the groups on the transfer task as function of the amount of practice received during training. A limitation of the research design may have contributed to this lack of distinction between the groups at the beginning of transfer. The experiment was carried out in one sitting, irrespective of how many training sessions the participant received. This may have led to fatigue on the part of participants exposed to the more lengthy training session, which in turn

may have diminished performance. The one experimental sitting may have also interfered with the amount of forgetting that can occur when skills are not being practiced.

Research into the nature of forgetting is mixed with some research suggesting that that well-practiced skills do not decay with disuse, while other research has demonstrated that the amount of forgetting appears relatively small in comparison to the amount of improvement with practice (Anderson, 1992; Loftus, 1985). Other research has demonstrated that any decline in automatic performance over time appears to follow a power function (Anderson & Schooler, 1991; Grant & Logan, 1993). In this experiment, by completing all stages of the training phase and the transfer phase in one sitting, the level of forgetting, particularly of general skills, as a function of the amount of practice, may not have been tested adequately. If the experimental process was extended over a longer time period so that each training session was conducted on a separate day and the transfer phase presented on the day following the last training session, differences in performance between the groups on the transfer task may be more likely to be detected. By increasing the delay between training sessions, general skills may decay to a greater extent, but the strength of the specific skills would be reinstated with the first few trials of each new training session. Hence, this type of experiment would be more likely to produce differences in initial transfer performance that is a function of amount of increased training.

Conclusions

The results of this experiment support the notion that practice leads to improved performance. However, the nature by which the improved performance

occurs has come under scrutiny. Logan's Instance theory (1988, 1990) was presented as an example of a specific theory of skill acquisition, in which many of the features of the development of automatic performance are accounted for by the effects of practice on memory retrieval processes. In contrast, the ACT* theory (Anderson, 1982, 1987) provides a comprehensive account of the manner in which general skills are acquired, however it does offer some explanation as to how specific skills may also be acquired. Anderson (1982, 1987) makes predictions that skills can be applied beyond the training experiences, while Logan (1988, 1990) proposes that skills are highly specific in nature, constrained to the events encountered during training.

This experiment highlights some of the limitations of the Instance theory. In particular the theory is unable to account for the observed partial positive transfer of skills from the training to the transfer task. Furthermore, the theory could not explain the fact that the amount by which performance was disrupted with the change in x and y values appeared to be a function of the amount of practice on the training task. The "all or nothing" stance Logan adopts regarding the transfer of skills suggests that an instance can help participants do all of a task or none of a task. The theory contains no mechanism by which an instance can be partially useful (Speelman & Kirsner, 1997).

In providing further evidence that skill acquisition can be both general and specific this study supports the findings of Greig and Speelman (in press). The nature of skill acquisition and transfer observed in this experiment appears to be consistent with the proposed mechanisms underlying skill acquisition outlined in the ACT* theory (Anderson, 1982, 1987, 1992). The study further demonstrates that increased practice can lead to improved performance on a similar yet different task, with

disruptions in performance influenced by the amount of practice received prior to the presentation of the new item.

With respect to the real life situation that opened this thesis, the results of this experiment have a number of implications for individuals completing a course in word processing. Firstly, the practice received in the classroom setting is beneficial when they first apply these skills outside the classroom. Secondly, this research further illustrates that word processor operators who practice with particular software package and keyboard for long periods can expect greater disruptions when transferring to a new software than someone with a lot less practice using the old software package.

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Appendix A

Information Letter and Consent Form

Dear Student,

I am currently examining the manner in which we acquire mental skills and the effect of training on performance as part of my Honours research project in the School of Psychology at Edith Cowan University. This experiment conforms to the guidelines produced by the Edith Cowan University Committee for the Conduct of Ethical Research.

In the experiment, you will be asked to solve some simple math's problems. They will be presented to you on the computer screen and you will be required to enter your response into the computer using the mouse. Please do not be concerned if you have never done anything like this before, as most of the other subjects are the same as you in this respect. The aim of the experiment is to look at how performance of the task is influenced by practice. Your participation in this experiment will involved one session lasting between one to two hours. You will be paid \$5.00 for your time and assistance. I will also provide some refreshments.

Your participation is completely voluntary, so you do not have to take part in this research if you do not wish to. If you agree to participate you are free to withdraw from the project at any time. I will not ask for your full name and I will be the only person with access to your responses and any other information collected. Please be assured your responses will be treated in a confidential manner. If the research data gathered for this study is published, you will not be identifiable. At the conclusion of this study, a report of the results will be available upon request.

Please do not hesitate to direct any queries about the research to either myself or my supervisor. Contact details for both myself and my supervisor are listed below.

Your assistance in this project will be greatly appreciated.

Sincerely,

Tracey Piani.

Student: Tracey Piani
School of Psychology
Edith Cowan University
Ph: 9370 1173 (lm).

Supervisor: Dr. C. Speelman
School of Psychology
Edith Cowan University
Ph: 9400 5724.

I (the participant) have read the information outlined and any questions I have, have been answered to my satisfaction. I agree to participate in this activity, realizing I may withdraw at any time. I agree that the research data gathered for this study may be published, provided I am not identifiable

Signature _____

Date _____

Investigator _____

Date _____

Name (first name is sufficient): _____

Contact phone number: _____

Appendix B

Accuracy Output Summary Tables

SPANOVA Summary Tables of Accuracy Scores for Initial Training Phase

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
Intercept	93990.688	1	93990.688	8632.064	.000	8632.064	1.000
COND	13.758	2	6.879	.632	.537	1.264	.148
Error	424.654	39	10.889				

a. Computed using alpha = .05

Tests of Within-Subjects Effects

Measure: MEASURE_1

Sphericity Assumed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
BLOCK	108.646	39	2.786	6.929	.000	270.242	1.000
BLOCK * COND	38.785	78	.497	1.236	.083	96.424	1.000
Error(BLOCK)	611.489	1521	.402				

a. Computed using alpha = .05

SPANOVA Summary Tables of Accuracy Scores for Final Training Phase

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
Intercept	98777.336	1	98777.336	13598.867	.000	13598.867	1.000
COND	10.832	2	5.416	.746	.481	1.491	.167
Error	283.282	39	7.264				

a. Computed using alpha = .05

Tests of Within-Subjects Effects

Measure: MEASURE_1

Sphericity Assumed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
BLOCK	24.093	39	.618	2.337	.000	91.156	1.000
BLOCK * COND	26.454	78	.339	1.283	.052	100.088	1.000
Error(BLOCK)	402.004	1521	.264				

a. Computed using alpha = .05

SPANOVA Summary Tables of Accuracy Scores for Transfer Phase

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
Intercept	89031.488	1	89031.488	4993.728	.000	4993.728	1.000
COND	13.294	2	6.647	.373	.691	.746	.106
Error	695.318	39	17.829				

a. Computed using alpha = .05

Tests of Within-Subjects Effects

Measure: MEASURE_1

Sphericity Assumed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
BLOCK	301.322	39	7.726	11.419	.000	445.347	1.000
BLOCK * COND	35.468	78	.455	.672	.987	52.421	.947
Error(BLOCK)	1029.111	1521	.677				

a. Computed using alpha = .05

Appendix C

Reaction Time Summary Tables for the Training Phase.

SPANOVA Summary Tables of Reaction Time Scores for Initial Training Phase (Trial Blocks 1-40).

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
Intercept	2.2E+10	1	2.2E+10	437.896	.000	437.896	1.000
COND	6.2E+07	2	3.1E+07	.609	.549	1.219	.144
Error	2.0E+09	39	5.1E+07				

a. Computed using alpha = .05

Tests of Within-Subjects Effects

Measure: MEASURE_1

Sphericity Assumed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
BLOCK	5.0E+09	39	1.3E+08	89.357	.000	3484.908	1.000
BLOCK * COND	7.0E+07	78	902424.8	.631	.995	49.236	.927
Error(BLOCK)	2.2E+09	1521	1429630				

a. Computed using alpha = .05

SPANOVA Summary Tables of Reaction Time Scores for Final Training Phase: (Last 40 Trial Blocks).

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
Intercept	9.0E+09	1	9.0E+09	615.002	.000	615.002	1.000
COND	1.4E+09	2	7.2E+08	48.973	.000	97.946	1.000
Error	5.7E+08	39	1.5E+07				

a. Computed using alpha = .05

Tests of Within-Subjects Effects

Measure: MEASURE_1

Sphericity Assumed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
BLOCK	7.8E+08	39	2.0E+07	48.918	.000	1907.821	1.000
BLOCK * COND	8.7E+08	78	1.1E+07	27.210	.000	2122.362	1.000
Error(BLOCK)	6.2E+08	1521	409363.0				

a. Computed using alpha = .05

ANOVA Summary Tables of Reaction Time Scores for Last Trial Items (Last Training Block)

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
B40	Between Groups	3745560	2	1872780	3.881	.029
	Within Groups	1.9E+07	39	482495.1		
	Total	2.3E+07	41			

Post Hoc Comparison: Tukey HSD for Last Trial Block Items (Last Training Block)

Multiple Comparisons

Dependent Variable: B40

Tukey HSD

(I) condition	(J) condition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1xtr	2xtr	355.4693	262.541	.375	-284.1619	995.1005
	3xtr	731.3962*	262.541	.022	91.7650	1371.0275
2xtr	1xtr	-355.4693	262.541	.375	-995.1005	284.1619
	3xtr	375.9269	262.541	.335	-263.7043	1015.5581
3xtr	1xtr	-731.3962*	262.541	.022	-1371.03	-91.7650
	2xtr	-375.9269	262.541	.335	-1015.56	263.7043

*. The mean difference is significant at the .05 level.

Appendix D

Reaction Time Output Summary Tables for the Transfer Phase.

SPANOVA Summary Tables of Reaction Time Scores for the Transfer Phase

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
Intercept	1.2E+10	1	1.2E+10	201.164	.000	201.164	1.000
COND	3.0E+07	2	1.5E+07	.248	.782	.496	.086
Error	2.3E+09	39	6.0E+07				

a. Computed using alpha = .05

Tests of Within-Subjects Effects

Measure: MEASURE_1

Sphericity Assumed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
FACTOR1	2.4E+09	39	6.2E+07	36.898	.000	1439.015	1.000
FACTOR1 * COND	6.4E+07	78	822258	.492	1.000	38.384	.812
Error(FACTOR1)	2.5E+09	1521	1670895				

a. Computed using alpha = .05

SPANOVA Summary Tables of Reaction Time Scores for the Final Training Block Items and Initial Transfer Block Items

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
Intercept	1.8E+09	1	1.8E+09	191.850	.000	191.850	1.000
COND	7486195	2	3743098	.404	.671	.807	.111
Error	3.6E+08	39	9276444				

a. Computed using alpha = .05

Tests of Within-Subjects Effects

Measure: MEASURE_1

Sphericity Assumed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
BL	6.7E+08	1	6.7E+08	75.613	.000	75.613	1.000
BL* COND	6427197	2	3213599	.363	.698	.726	.104
Error(BL)	3.5E+08	39	8851750				

a. Computed using alpha = .05

Post Hoc Comparison: Tukey HSD for the Final Training Block Items and Initial Transfer Block Items

$$\frac{\sqrt{8851750}}{14}$$

$$= 795.153$$

Condition 1: Final Tr. Initial Tf.
(One training session)

$$\frac{7833 - 2152}{795.153}$$

$$= 7.144 * \text{sig, } p < 0.05$$

Condition 2: Final Tr. Initial Tf.
(Two training sessions)

$$\frac{6733 - 1786}{795.153}$$

$$= 6.221 * \text{sig, } p < 0.05$$

Condition 3: Final Tr. Initial Tf.
(Three training sessions)

$$\frac{7710 - 1411}{795.153}$$

$$= 7.921 * \text{sig, } p < 0.05$$

SPANOVA Summary Tables of Reaction Times For First Training Block Items and First Transfer Block Items Across Groups.

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
Intercept	6.7E+09	1	6.7E+09	207.868	.000	207.868	1.000
COND	5960844	2	2980422	.092	.912	.184	.083
Error	1.3E+09	39	3.2E+07				

a. Computed using alpha = .05

Tests of Within-Subjects Effects

Measure: MEASURE_1

Sphericity Assumed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
BLOCK	2.0E+08	1	2.0E+08	30.842	.000	30.842	1.000
BLOCK * COND	1.8E+07	2	8945528	1.405	.257	2.811	.283
Error(BLOCK)	2.5E+08	39	6365082				

a. Computed using alpha = .05

Post Hoc Comparison: Tukey HSD for the For First Training Block Items and First Transfer Block Items

$$\frac{\sqrt{6365082}}{14}$$

$$= 674.27$$

$$\begin{array}{l} \text{Condition 1: Initial Tr. Initial Tf.} \\ \text{(One training session)} \end{array} \quad \frac{10808 - 7833}{674.27}$$

$$= 74.412 * \text{sig, } p < 0.05$$

Condition 2: Initial Tr. Initial Tf. 10960 - 6733
(Two training sessions) 674.27

= 15.25 * sig, $p < 0.05$

Condition 3: Initial Tr. Initial Tf. 9680 - 7710
(Three training sessions) 674.27

= 2.92 * sig, $p < 0.05$